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Comparison of various beam tunes for MIPP secondary beam line

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Abstract

We compare various beam tunes in the MIPP secondary beam with a view to optimize spray, momentum dispersion and beam divergence and spot-size at the secondary target. We come up with a recommendation on the tune to run and also criteria for improving tunes further.

I. INTRODUCTION

We generated the phase space of 10,000 secondary particles coming from our primary copper target with a uniform distribution in x and y of 0.5 cm in width, the transverse size of our primary target. The angular divergence generated in x' and y' of the beam was uniform between -2 milliradians and 2 milliradians. The momentum spread of the generated beam was Gaussian with a sigma in $\delta p/p = 2\%$.

The same input particles were propagated through the beamline program MAD for various different beam tunes and the secondary beam quantities were studied. The alignments and positions of the MIPP secondary beamline elements were painstakingly entered into MAD for this study. We demanded that the secondary beam particles pass through the collimator MC6CY set at 3mm and that they impinge on our secondary target within an x and y window of $\pm 2\ cm$. The fraction that passed these cuts then gave a measure of the beam focus at the secondary target and the momentum spread transmitted gave a measure of the efficacy of the momentum collimator in selecting momentum- The smaller the momentum spread the better the efficiency of the collimator.

The angle θ of the beam in the lab with respect to the z axis should be held as close to zero as possible to aid the beam cerenkov reconstruction. We measure the mean value μ and rms σ of θ and compute the quantity $\alpha = \mu + 3\sigma$ in milliradians to get a measure of the divergence of the beam.

Using the algorithm outlined in [1], we predict particle by particle the $\delta p/p$ of the beam. We examine the width of the true value of $\delta p/p$-predicted value $\delta p/p$ to tell how well we can predict the beam momenta individually.

Finally, using data, we calculate the spray variable in the TPC. This is defined as the number of pads hit in the first 5 padrows of the TPC excluding the beam region. The mean and rms of the spray variable should be as small as possible to minimize the sprays of particles generated due to the beam scraping the beamline elements downstream of the momentum selection collimator.

II. TUNES EXAMINED

We consider in detail three different tunes which we title OPERATION, ANDRE and CAROL. We have studied other tunes, but these three were selected for detailed study. The OPERATION tune is the one currently in use. The ANDRE tune was arrived at by Andre and Valeri Lebedev using the program OPTIM with a view to minimize scraping downstream of the momentum collimator. The CAROL tune was produced [2] by Carol Johnstone using the program MAD.

Figure 1 gives a comparison of the optical functions (β_x, β_y and the dispersion in y) of the three beam lines as a function of the distance from the primary target. The momentum selection collimator is at 33.8 meters from the primary target and the seco dary target is at 95.84 meters. It can be seen that the OPERATION tune beta function β_y is very large after the momentum collimator which results in a large beam size and scraping. The value of β_x for the tune ANDRE at the secondary target also seems too large. Figure 2 gives the distribution of $\delta p/p \equiv \frac{p-p_0}{p_0}$ for each particle where p_0 is the nominal momentum that the beam is tuned to, i.e. the central trajectory. Figure 3 gives the divergence of the beam at the secondary target. This quantity θ is defined as the angle of the beam particle with respect to the z-axis (beam axis) at the secondary target and should be under ≈ 1 mrad for the beam cerenkovs to function correctly.

Using the algorithm outlined in [1] it is possible to predict the $\delta p/p$ particle by particle by using the quantities $\lambda_k, k = 1, 4$ measured for each beam particle using the beam chambers, where $\lambda_k, k = 1, 4$ is givenby x, x', y, y' of the beam trajectory at the target. The prediction algorithm can be expressed as

$$\frac{\delta p^{pred}}{p} = \sum_{k=1}^{k=4} w_k \lambda_k \tag{1}$$

where the weights w_k are given in terms of the H-matrix components [1] by

$$w_k = -\frac{H(k,5)}{H(5,5)} \tag{2}$$

Figure 4 shows the difference between the actual $\delta p/p$ and the predicted $\delta p/p$ for the beam. The reduction in the width of this plot from the corresponding one in Figure 2 gives us the a measure of how well we can predict this quantity beyond what is selected by the momentum selection collimator. The table I shows the various quantities of interest for

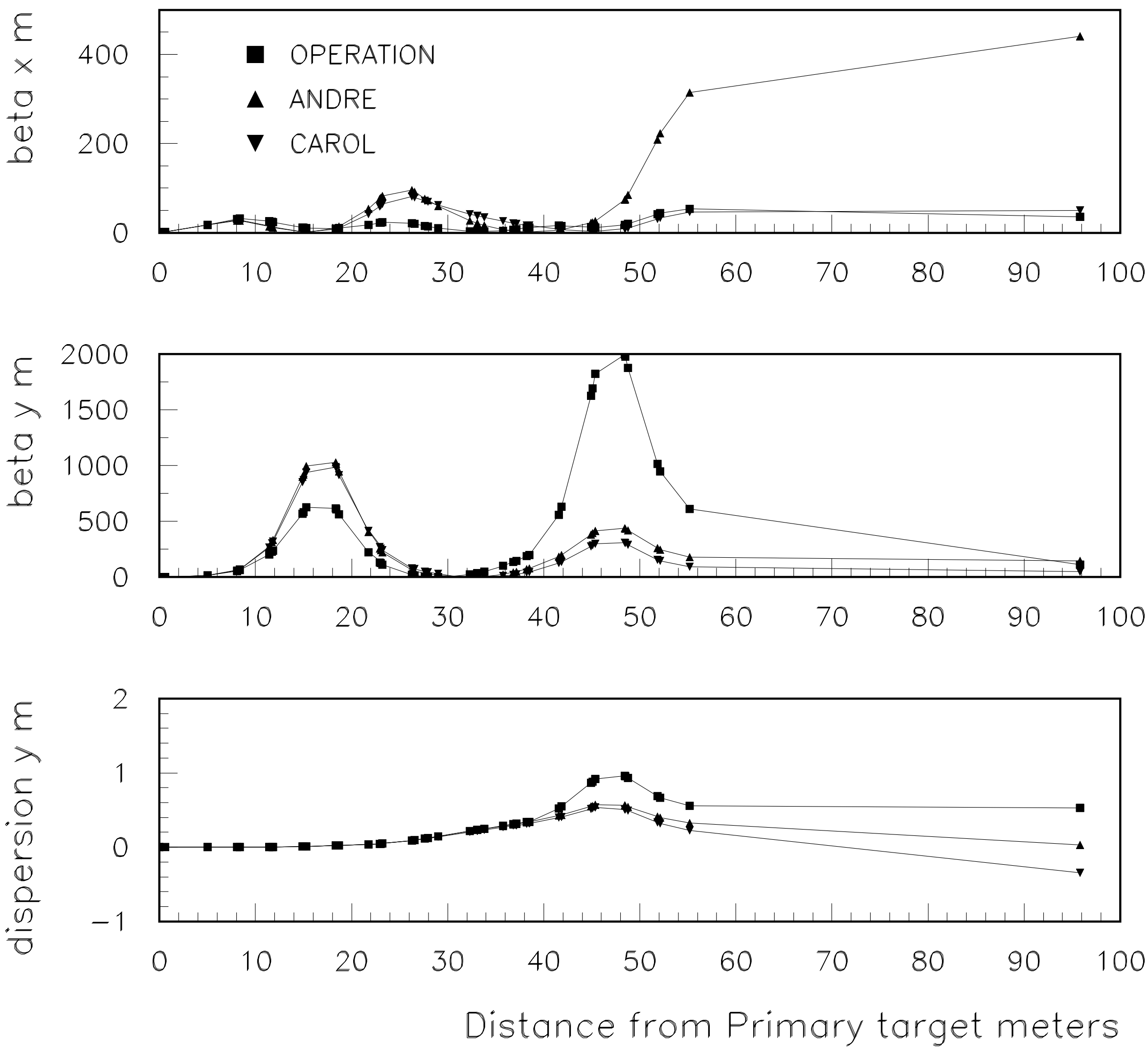

FIG. 1: Optical functions for the three different tunes

the three beamline tunes. It can be seen that the transmission on to target is highest for CAROL by almost a factor of three over the other two. This translates to better focussing at the secondary target. The OPERATION tune has the worst θ parameters. ANDRE has the best θ parameters, but that is obtained as a result of bad focussing in the x view. CAROL's θ parameters are within the guidelines. The dispersion at the collimator is the same for all tunes indicating that the momentum selection collimator efficacy is the same for all tunes. The table II gives the weights needed to multiply each measured quantity to predict the $\delta p/p$

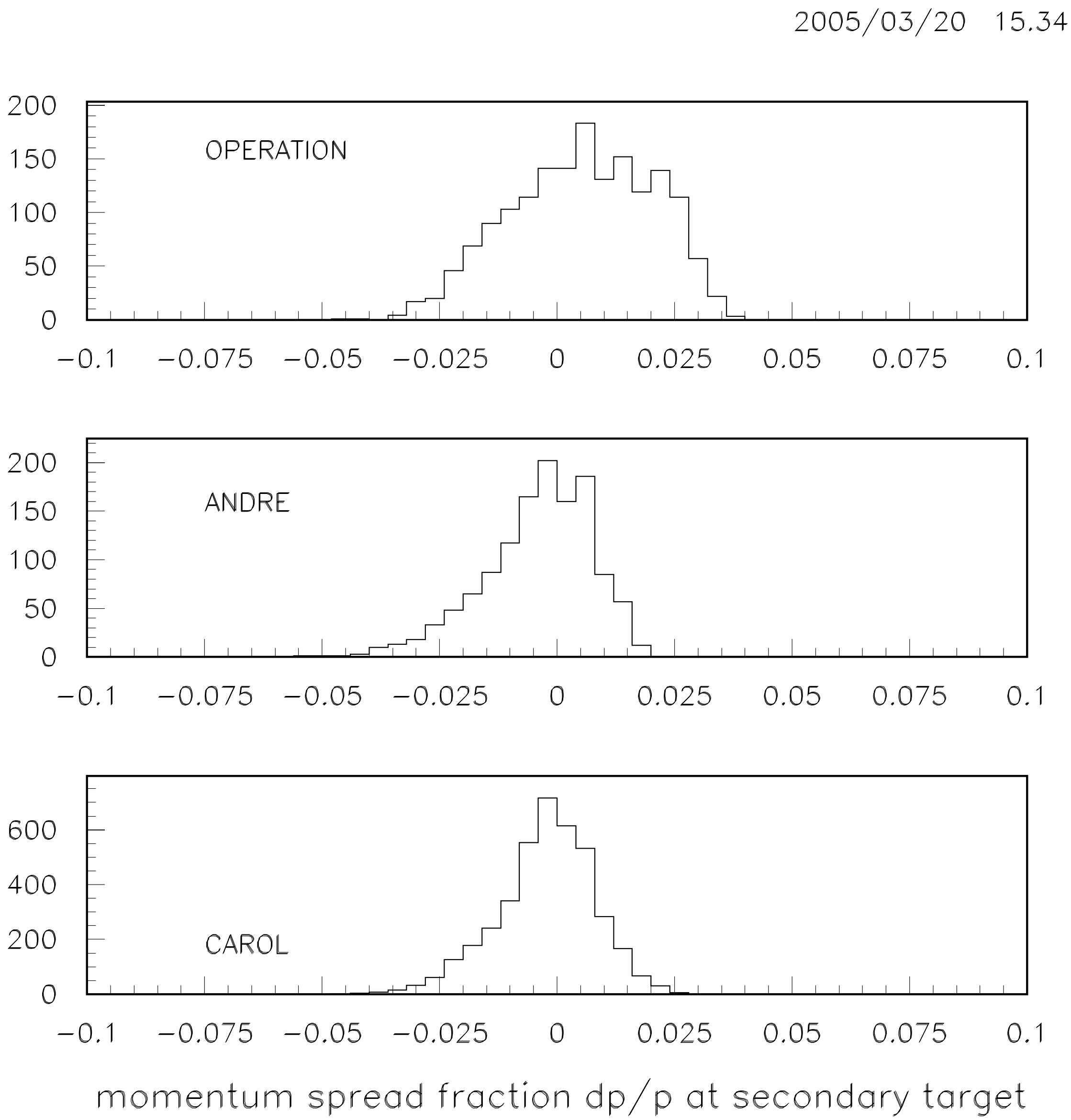

FIG. 2: Fractional difference from nominal momentum of the transmitted beam

for each tune. The ability to predict the $\delta p/p$ is slight with the present set of parameter, being the best (slightly) for CAROL, as can be seen from the quanity $\sigma(\delta p^{pred}/p - \delta p/p)$ in table I. Figure 5 shows the variation of the y at the target vs $\delta p/p$ for each tune. We need to find better tunes that provide a linear behavior at this plot. This would require tunes with non-zero dispersion at the target. What we are seeing is quadratic dispersion in both ANDRE and CAROL and a more linear dispertion in OPERATION. This translates to a 50% reduction in the width of the $\delta p/p$ for OPERATION as opposed to a 20% reduction in

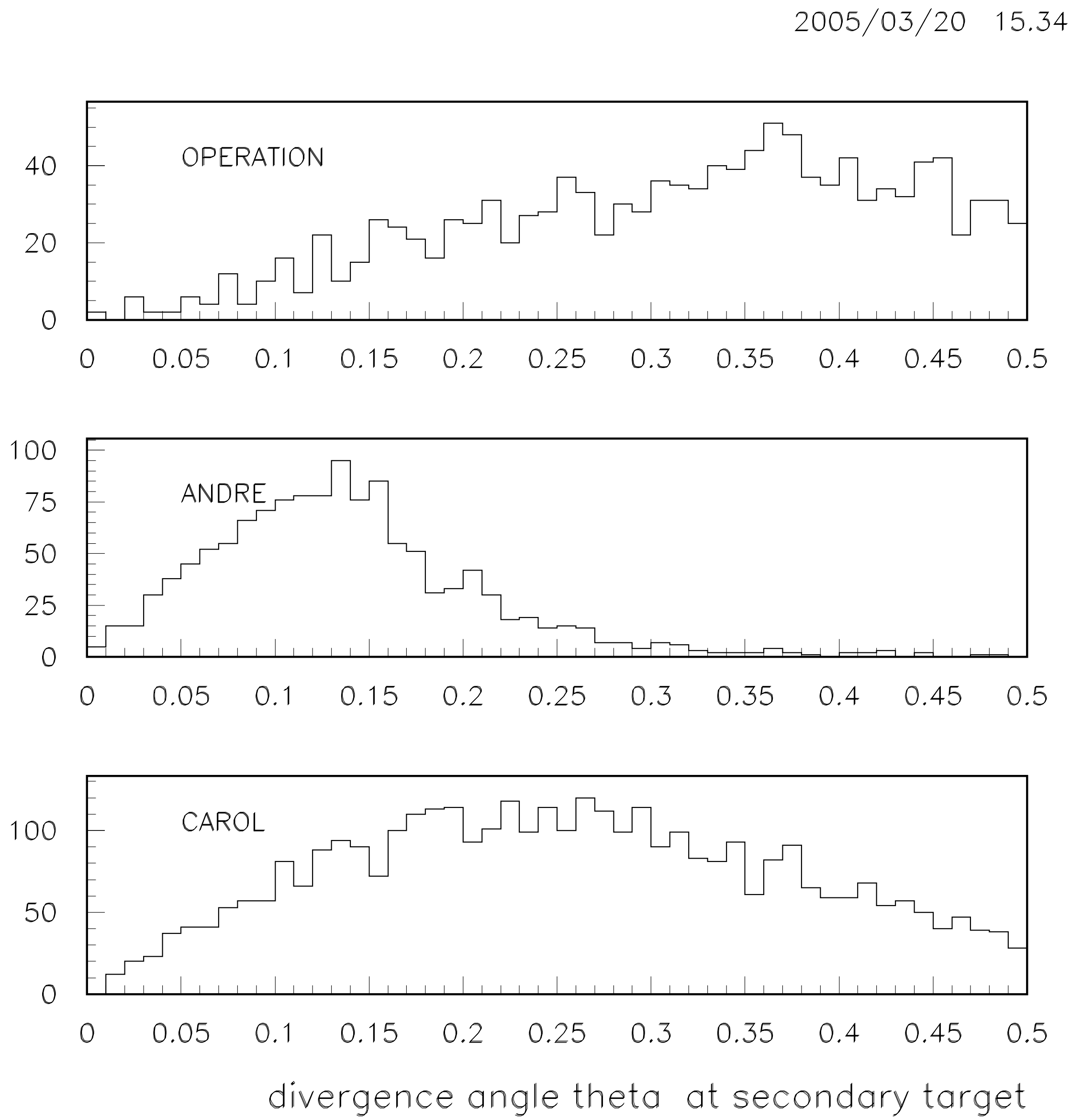

FIG. 3: Divergence of the beam with respect to z axis at the secondary target

the other two upon applying the prediction algorithm.

III. EXPERIMENTAL RESULTS

Figure 6 shows the distribution of the spray variable with the OPERATION tune at high intensity. Figures 7 and 8 show the corresponding plots for the tunes ANDRE and CAROL. It is clear that there is a substantial reduction in the spray variable in both ANDRE and

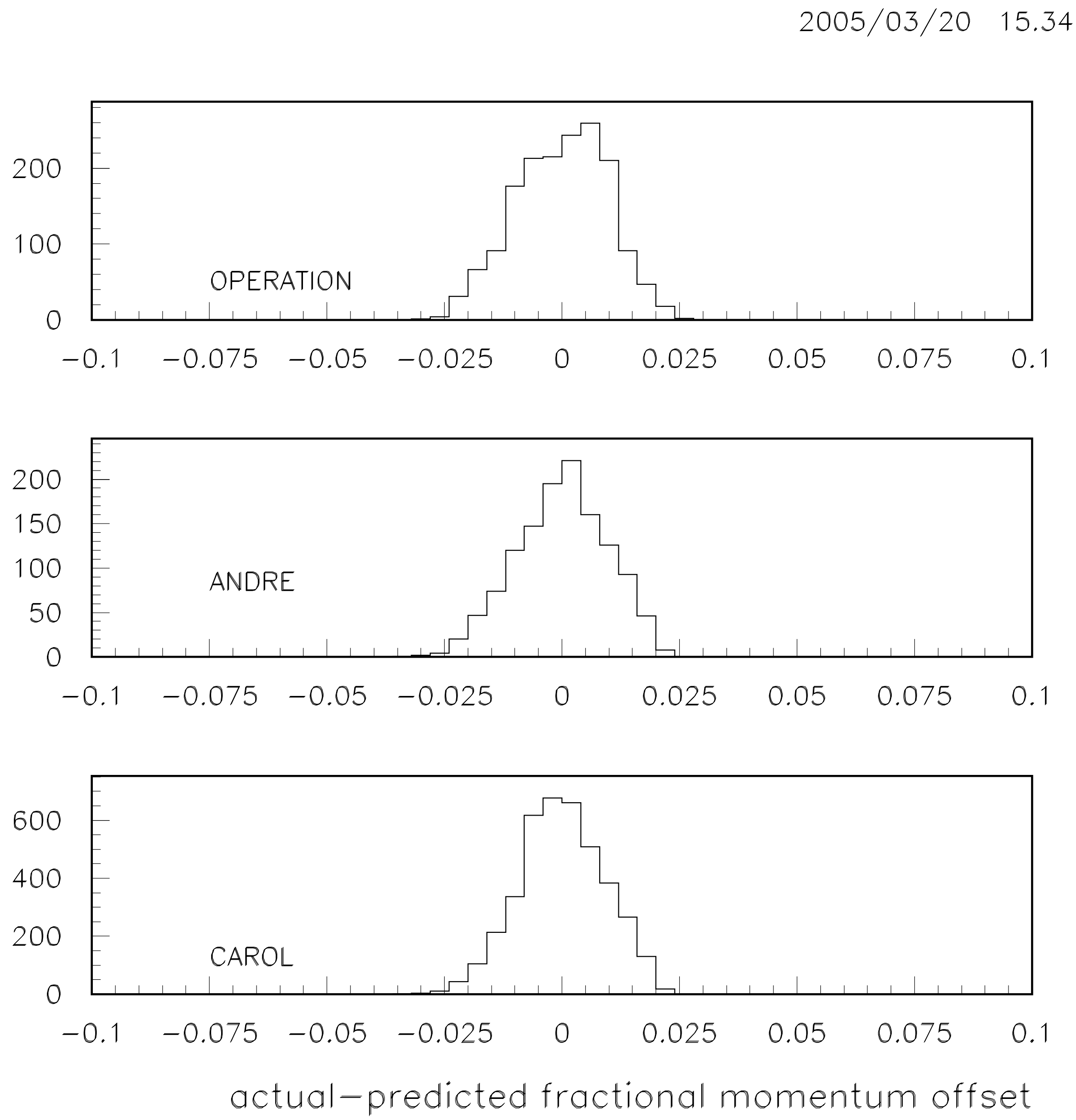

FIG. 4: Difference between the actual and predicted fractional momentum offset $\delta p/p$

CAROL and this can be understood in the reduction of the beta function β_y maxima in Figure 1 for both these tunes downstream of the collimator. Table III gives the comparison of the mean values of various experimental ratios for the three beam tunes.

TABLE I: Comparison of various quantities for the three beamline tunes.

	OPERATION	ANDRE	CAROL
Transmission	0.167	0.126	0.398
$< \theta >$	0.314	0.138	0.255
$\alpha \equiv < \theta > + 3\sigma_\theta$	0.656	0.352	0.602
dispersion at collimator(m)	0.247	0.246	0.230
$\sigma \delta p/p$	0.0151	0.0116	0.0104
$\sigma(\delta p^{pred}/p - \delta p/p)$	0.009747	0.009719	0.00909

TABLE II: Weights for predicting $\delta p/p$

Tune	x w_1	x' w_2	y w_3	y' w_4
OPERATION	0.27851E-03	0.12469E-02	0.45404E-02	0.26610E-01
ANDRE	0.21352E-03	0.15726E-02	-0.63034E-02	0.64459E-01
CAROL	-0.10464E-03	0.13332E-03	0.22797E-02	0.17744E-01

IV. CONCLUSIONS

It is clear that the tunes ANDRE and CAROL are superior to the OPERATION tune in reducing the spray in the TPC. This is achieved by reducing the beta function β_y to manageable levels. The beam sizes are proporional to $\sqrt{\beta_y}$ and thus scraping is reduced. The CAROL tune gives superior transmission and hence better focus at the target (in MAD). We thus recommend the adoption of the CAROL tune for further work in MIPP.

For improving tunes further, we recommend to investigate whether it is possible to keep the qualities of the CAROL tune and also get linear dispersin at the secondary target. This will improve our ability to predict the beam momentum particle by particle to better than 1%.

It should be noted that the beam is misaligned when coming into MC7 (SWIC MC7WC1 y). These SWICS have been aligned with respect to the beam chambers. So we can trust

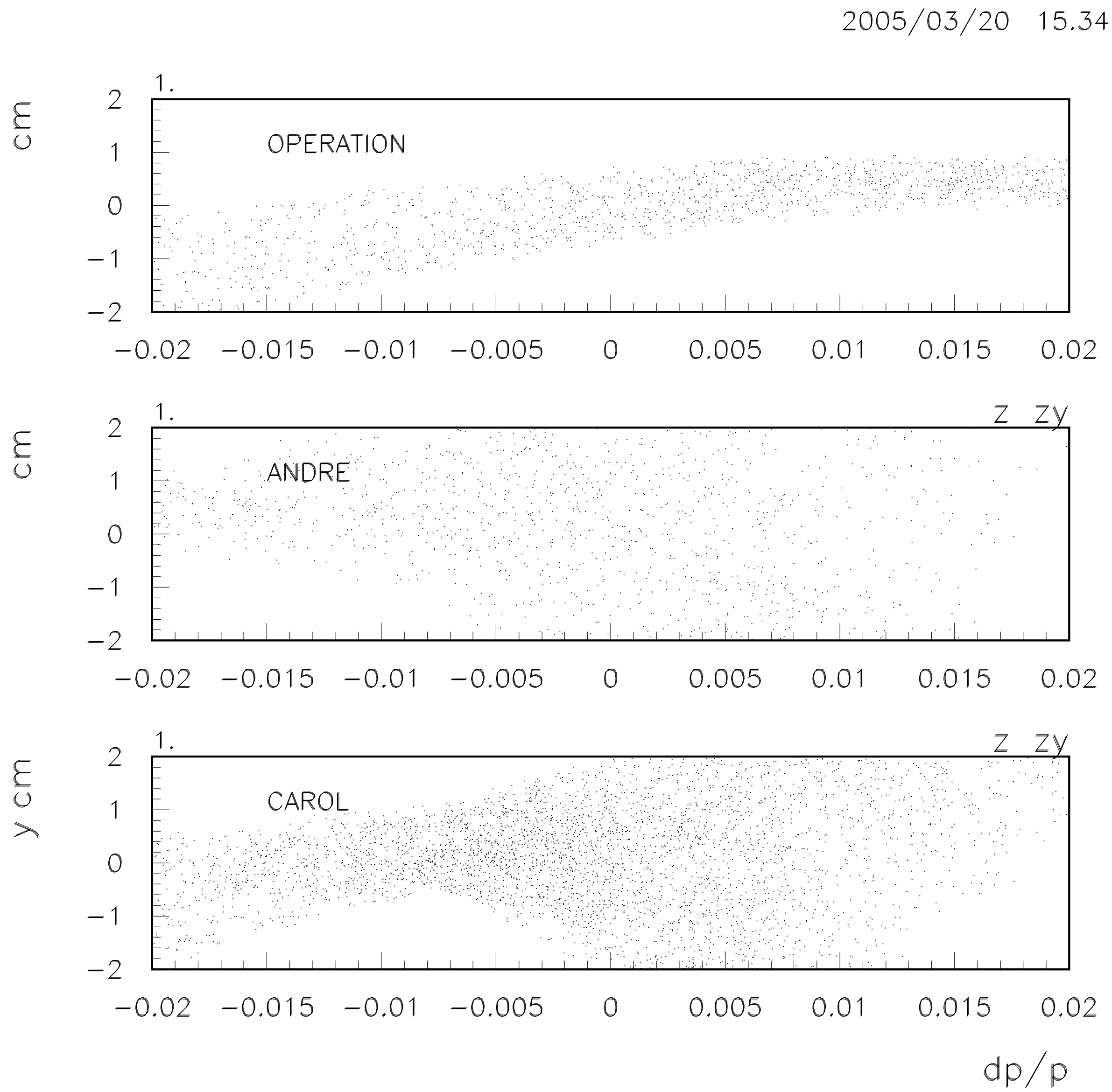

FIG. 5: Variation of vertical position y at the secondary target as a function of $\delta p/p$

their alignment. We should improve the CAROL tune by centering the beam in both MC7WC1 and MC7WC2 swics horizontally and vertically. This will improve our beam cerenkov performance even more.

V. APPENDIX

Figures 9, 10, and 11 show the parameter pages for the three different tunes.

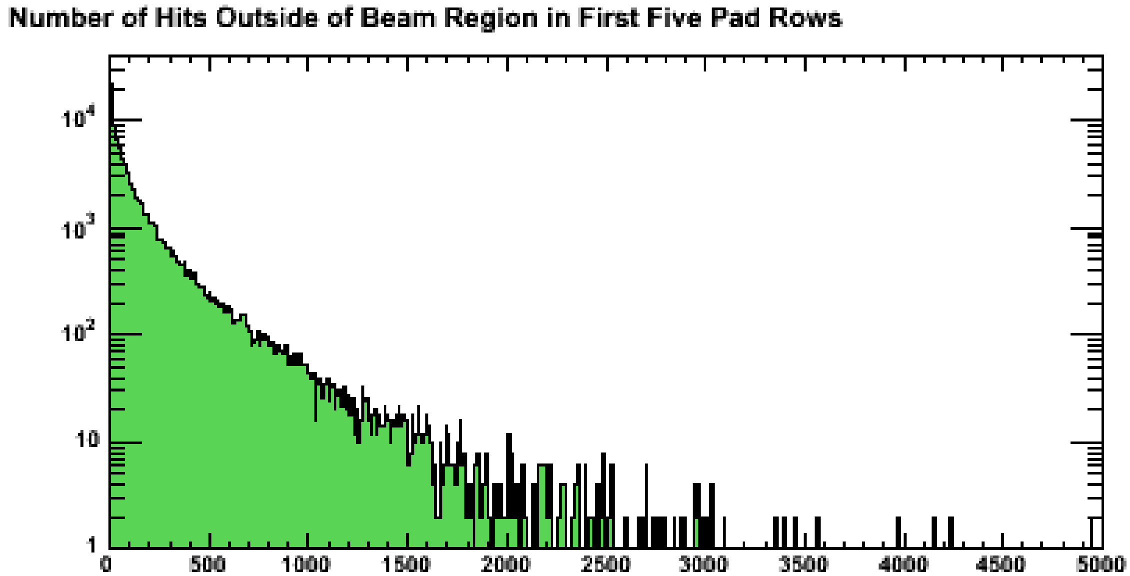

FIG. 6: Tune OPERATION: Distribution of the Spray variable in the TPC

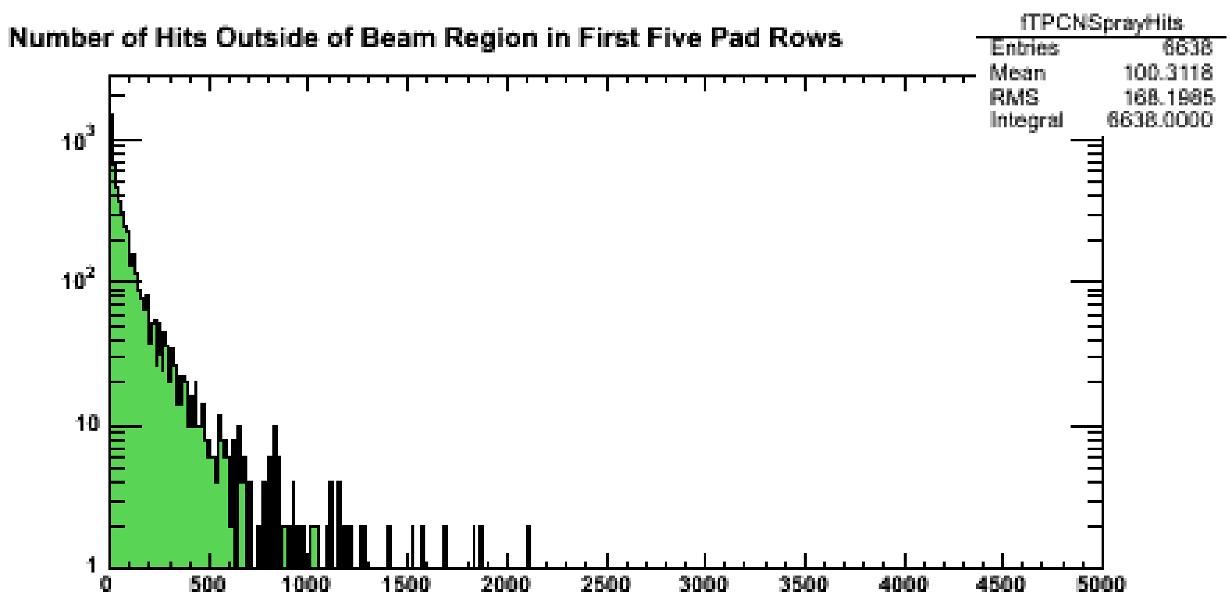

FIG. 7: Tune ANDRE: Distribution of the Spray variable in the TPC

Figures 12, 13, and 14 show the profiles in the SWICS for the three tunes at high intensity.

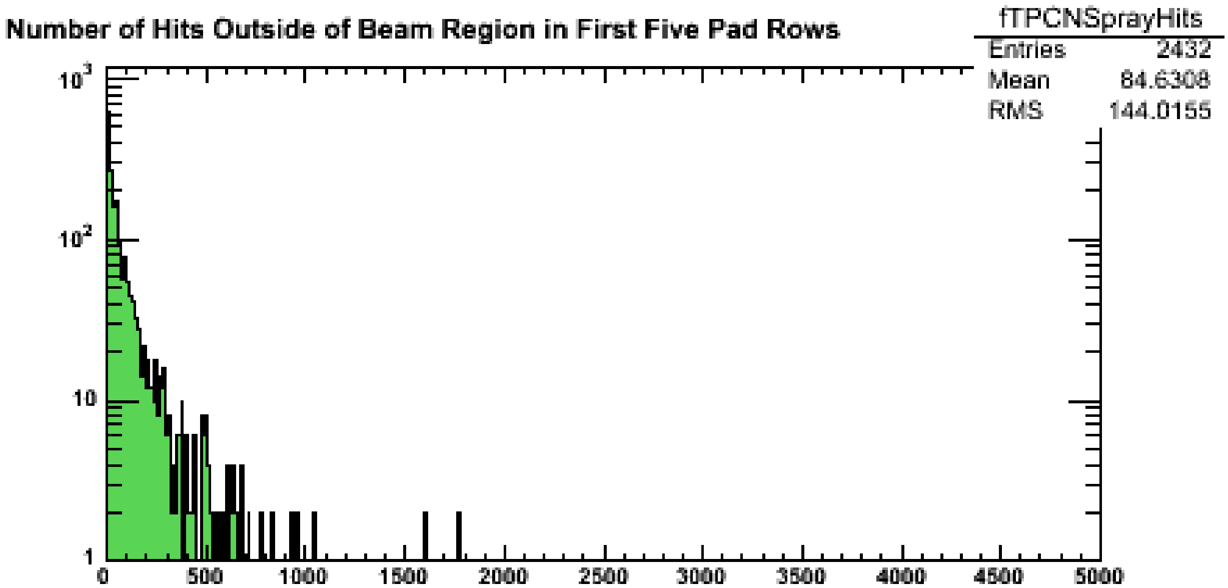

FIG. 8: Tune CAROL: Distribution of the Spray variable in the TPC

TABLE III: Comparison of various experimental quantities for the three beamline tunes.

	OPERATION	ANDRE	CAROL
Raw beam/T01	0.95	0.95	0.95
T00/T01	5.5	5.5	4.8
TBD/T01	1.4	1.15	1.2
Veto/T01	0.7	0.5	0.55
DC Interaction/T01	0.125	0.1	0.125
Veto/All beam	0.65	0.8	0.75

[1] "Algorithm to determine momentum of a beam particle using beam chamber tracks and the optics of the line", R.Raja, MIPP Note 57, http://ppd.fnal.gov/experiments/e907/notes/MIPPnotes/public/pdf/MIPP0057/MIPP0057.pdf

[2] The actual tune used was the one tagged final3_3mm.dat

*3/5*3/5

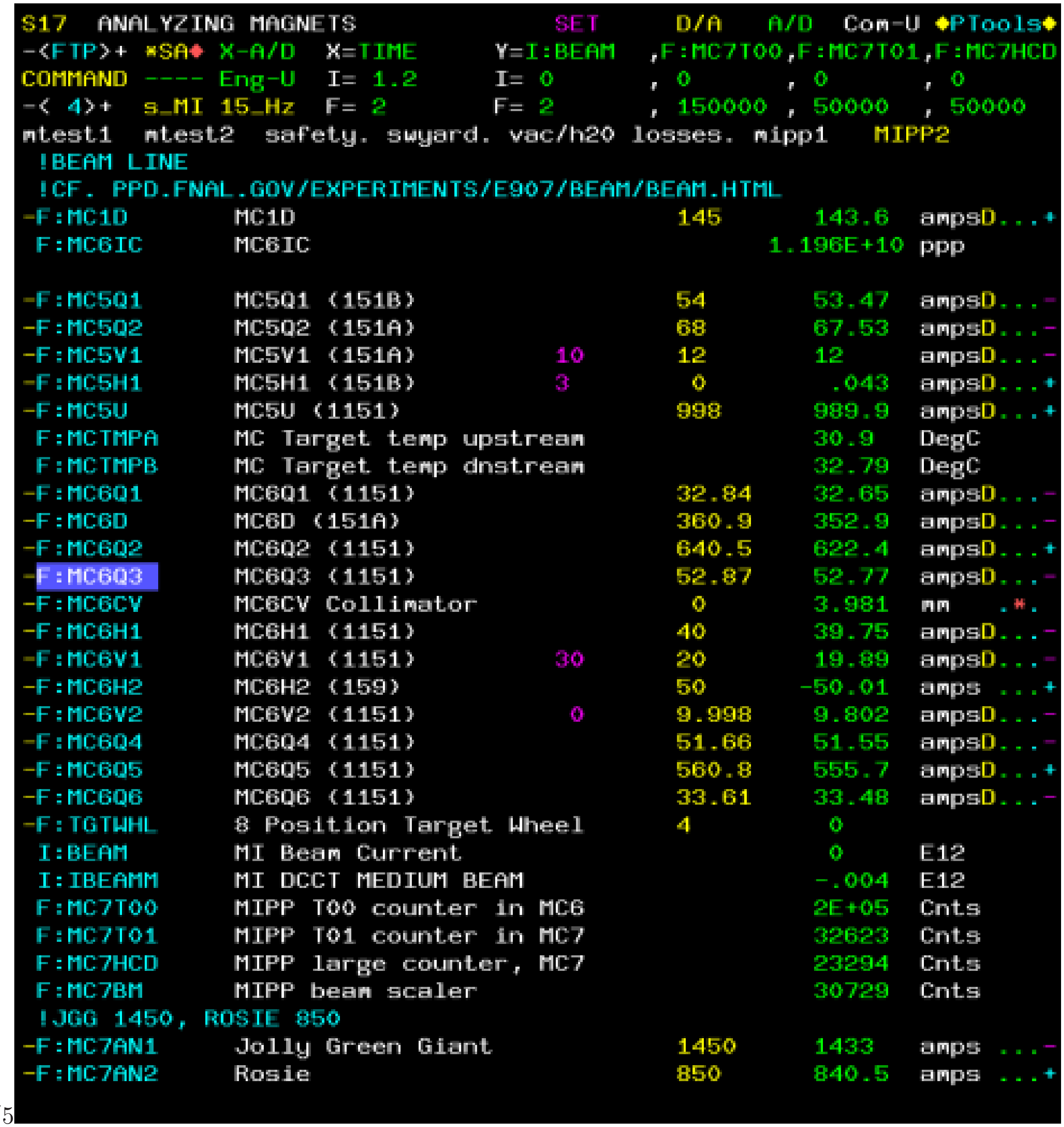

FIG. 9: Tune OPERATION: Parameters at -50GeV/c

*3/5*3/5

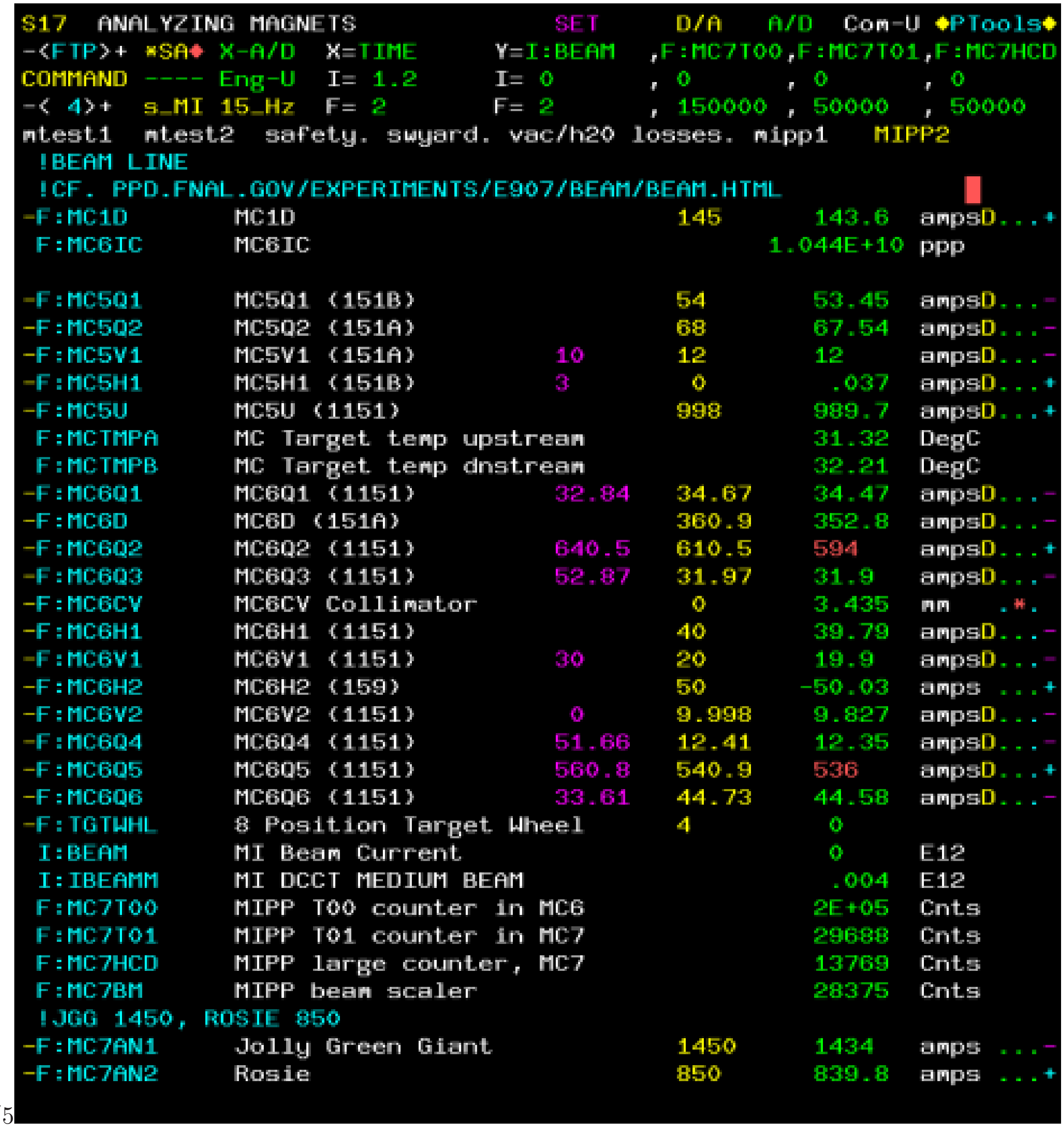

FIG. 10: Tune ANDRE: Parameters at -50GeV/c

*3/5*3/5

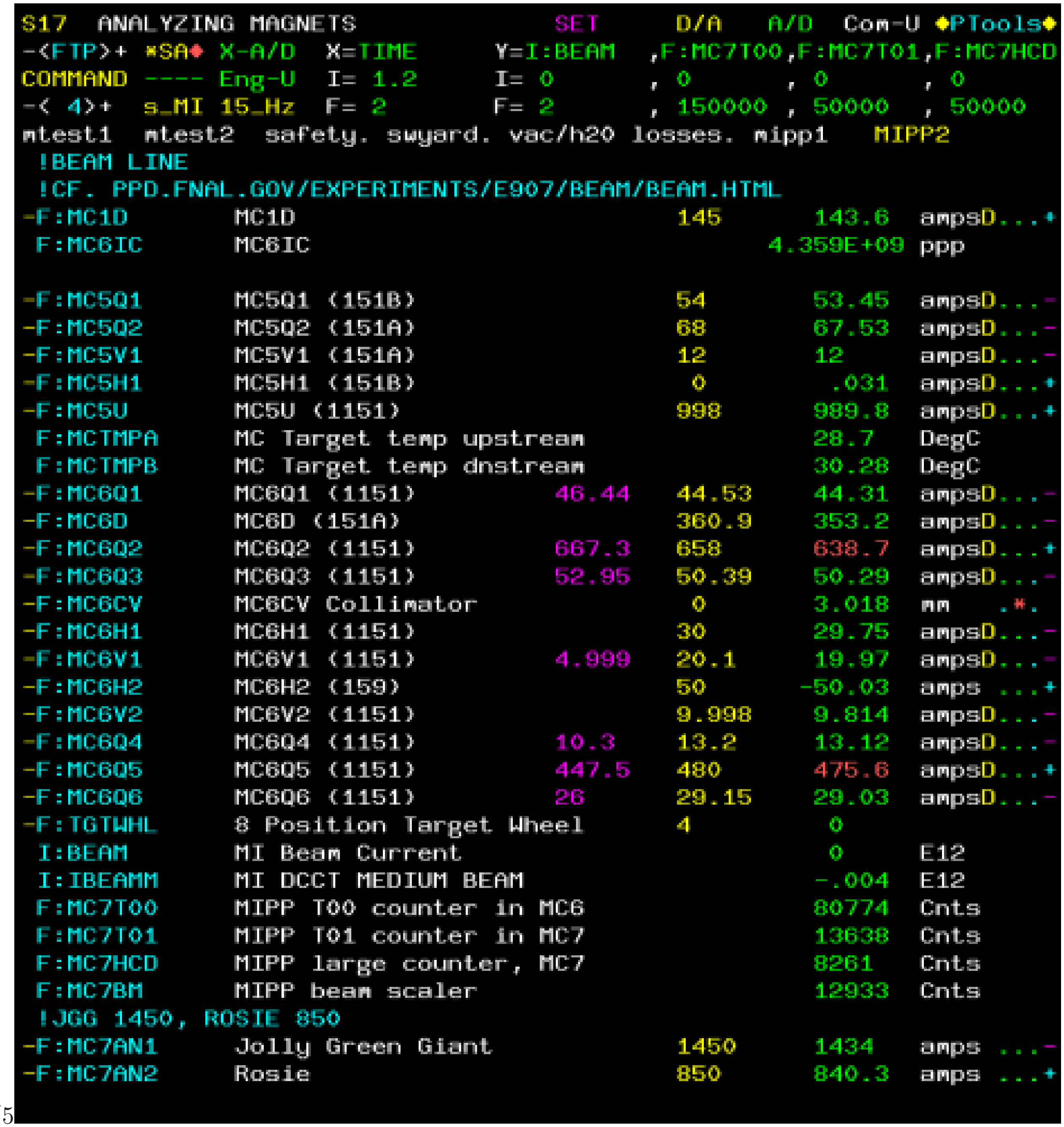

FIG. 11: Tune CAROL: Parameters at -50GeV/c

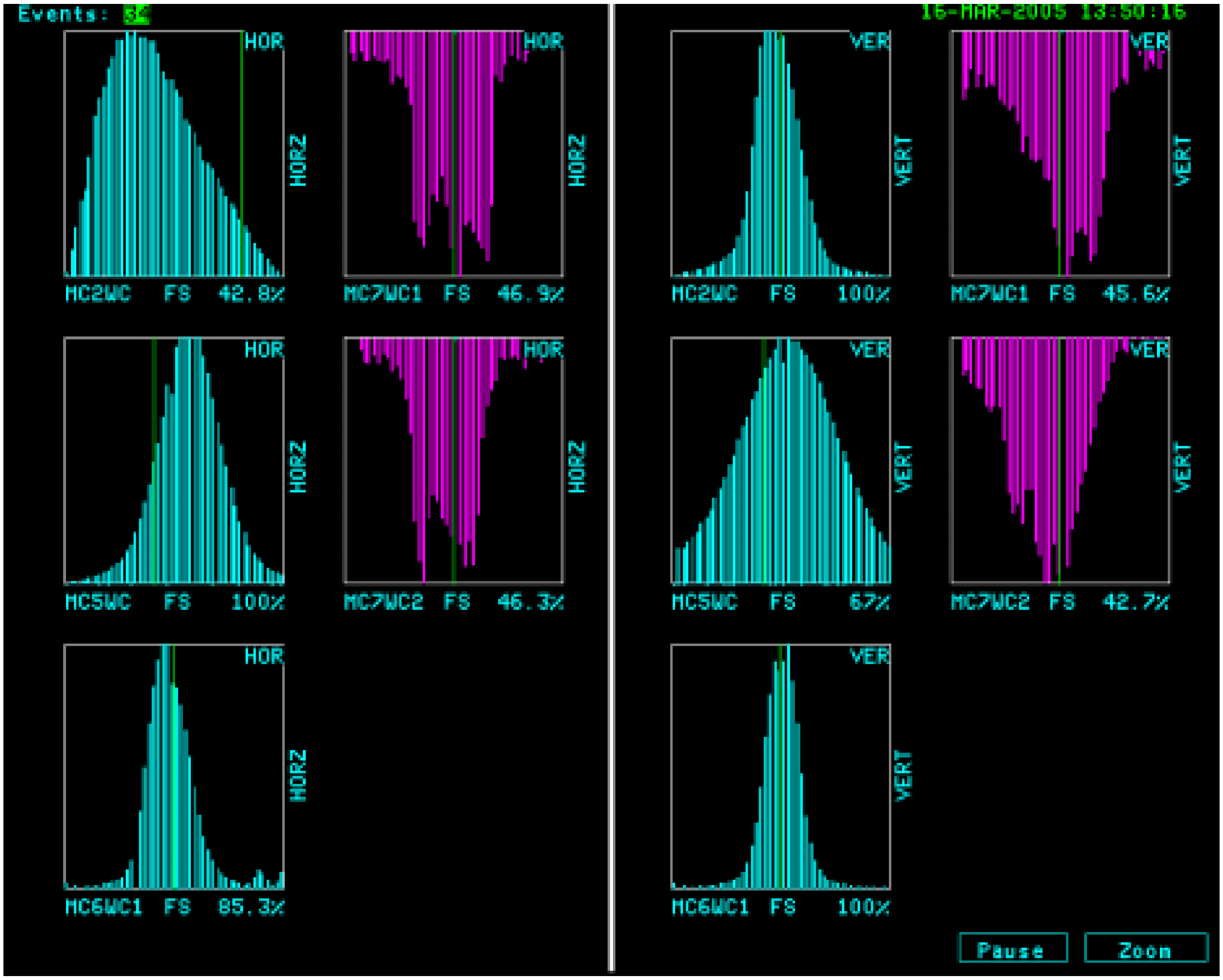

FIG. 12: Tune OPERATION: SWIC profiles

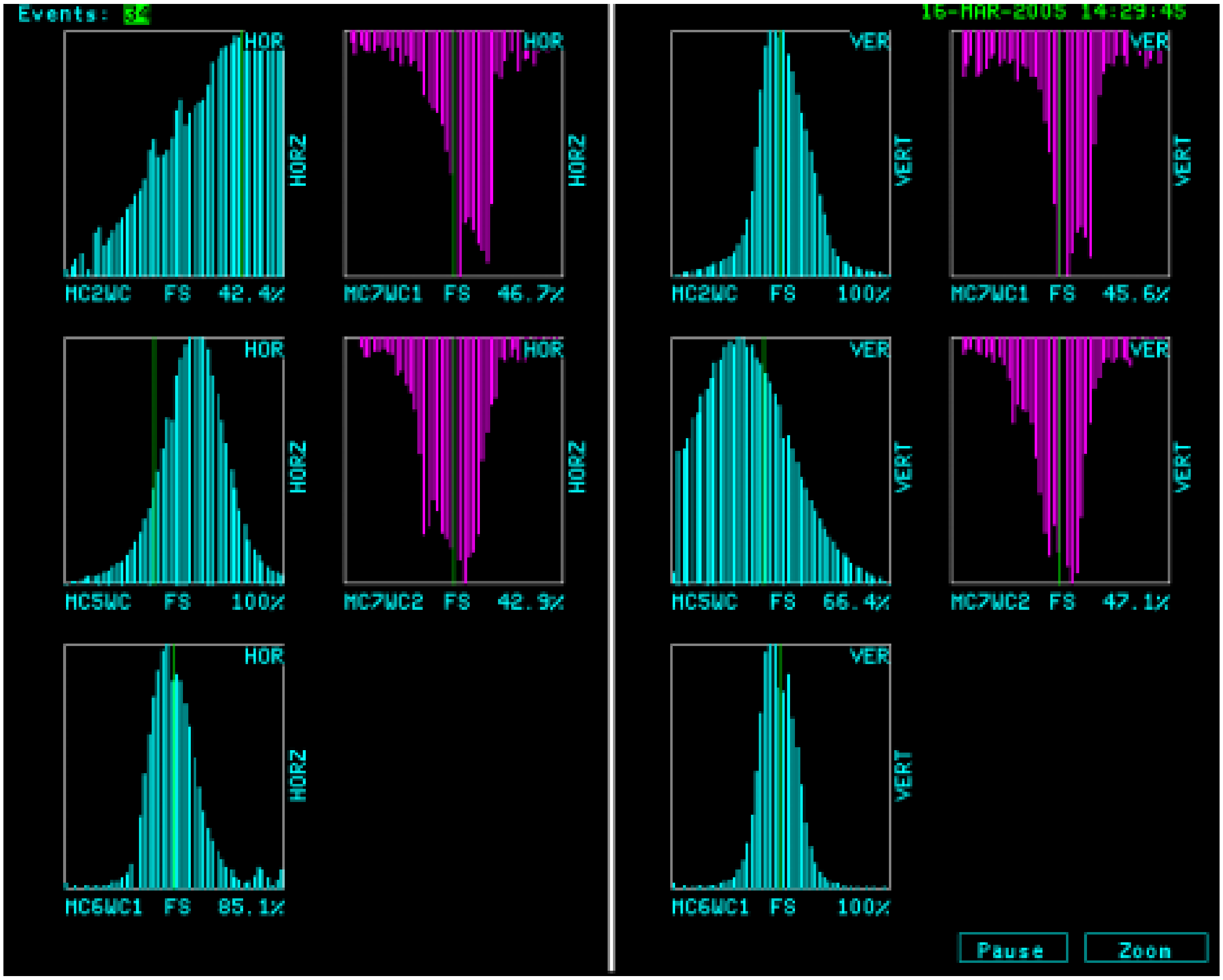

FIG. 13: Tune ANDRE: SWIC profiles

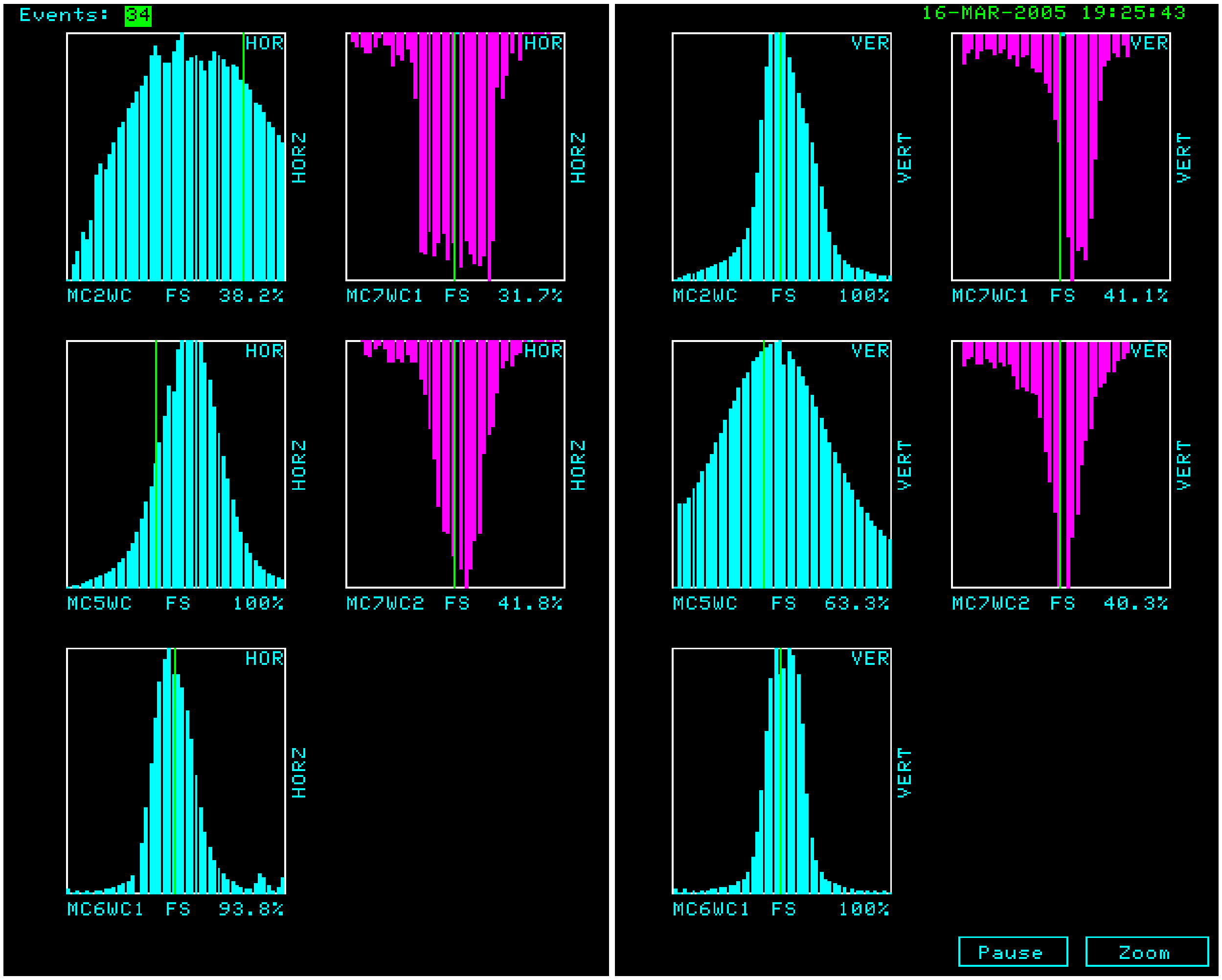

FIG. 14: Tune CAROL: SWIC profiles